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HIGH TURBIDITY AFFECTS FILTRATION RATE AND PSEUDOFAECES PRODUCTION OF THE MUD CLAM *Polymesoda erosa* (SOLANDER 1786) (BIVALVIA: CORBICULIDAE)

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ABSTRACT

Polymesoda erosa is an economically and ecologically important bivalve which thrives in brackish water mangroves or *Nypa* zones. Unpredictable weather conditions and unregulated anthropogenic activities in mangrove area can lead to high turbidity conditions and possibly affect the filtering capacity of *P. erosa*. This study will aid in the development of culture technique of this species in the region. Results could also be used to facilitate adequate stock management for potential commercial exploitation in Central Philippines. A laboratory experiment was conducted to determine the effects of turbidity concentration and body size on the filtration rate and pseudofaeces production of *P. erosa*. Filtration rates significantly increased with higher turbidity concentration up to 750 mg/L (p < 0.05). Pseudofaeces production also increased with increasing turbidity concentration (p < 0.05). Body size did not affect the filtration and pseudofaeces production of *P. erosa*. Results suggested that *P. erosa* was resilient to highly disturbed turbid environments and therefore, could be a potential candidate species for aquaculture.

Keywords: biodeposit, Bohol, *Nypa*, *Polymesoda erosa,* pseudofaces production, silt, suspension filter-feeders

INTRODUCTION

Development in a country is coupled with increasing demand for food that could be sourced out from aquatic ecosystems. Among many aquatic species, bivalves are now heavily cultured to meet such demand, yet there are still some fisheries that heavily rely on the wild stock, but with high potential for mariculture (Nuryanto & Susanto 2010). Understanding the physiological and ecological attributes of a species is crucial in deciding its mariculture feasibility. Such species include the mangrove or

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mud clam, *Polymesoda erosa* (Solander 1786), synonymously known as *Geloina coaxans* (Morton 1984). *P. erosa* is widely distributed in the Indo-Pacific region (Morton 1984, Nuryanto & Susanto 2010). It is also found in northern Australia as component of earth mounds (Gimin *et al.* 2004, Brookwell 2006). *P. erosa* possesses some characteristics that make it both an economically and ecologically important species. This clam is a potential source of bioactive compounds exhibiting antiviral (Chatterji *et al.* 2002) and antimicrobial (Sharma *et al.* 2009) properties. Its congeneric species, *P. caroliniana* is found in 16 estuaries in Mexico and is part of Mexico's commercial fishery (Wakida-Kusunoki & MacKenzie 2004) while *P. erosa* is also heavily exploited in the artisanal fishery in India (Clemente & Ingole 2009), Malaysia (Hamli *et al.* 2012), Indonesia (Hardinsyah *et al.* 2006), Northern Australia (Gimin *et al.* 2005) and Philippines (Germano *et al.* 2003, Laureta 2008). *Polymesoda* is noted to be harvested and traded in Bohol, Central Philippines (Argente 2012).

Biological studies showed that *P. erosa* is dioecious and hermaphrodite (Morton 1988), with no external dimorphism (Clemente & Ingole 2009) but with high polymorphism (Nuryanto & Susanto 2010). It can attain a size of 110 mm shell length (Morton 1988). In Goa, India where it is an exploited fishery product, adult shell density is 9 ind./m^2, described to be of non-random, patchy distribution (Clemente & Ingole 2011). Clam harvest is still done by hand gleaning between *Nypa* thickets.

P. erosa thrives in extreme adverse environmental conditions like low pH (Morton 1976); in waters with high heavy metal concentration (Modassir 2000), and high turbidity (Yap & Mohd Azri 2009). It is an oligohaline species (Morton & Chan 1986). Field studies have reported that *P. erosa* thrives in brackish water environments with salinity ranges of 7-31 ppt (Clemente & Ingole 2009, Yap & Mohd Azri 2009) but probably prefer higher salinity range since the low tide mark does not support adult population (Clemente & Ingole 2011). It can be found in areas only inundated during very high spring tides (Clemente & Ingole 2011), with ability to rapidly resume filter feeding activity when inundated (Yap & Mohd Azri 2009). *P. erosa* thrives well in true mangrove dominated area or in *Nypa fruticans* dominated estuarine area.

P. erosa is a filter feeder, referred as suspensivore by Wakida-Kusunoki and MacKenzie (2004), with ability to remove particles from water current by bio-filter mechanism accomplished by the gills (Ruppert & Barnes 1994). This form of nutrient acquisition significantly contributes to bentho-pelagic coupling (Barnes 2006, Jones *et al.* 2011). The removal of suspended particles in the water column by filter feeding results in the production of biodeposits (Clavier & Chauvaud 2010); particles coated with mucus which are processed in the mantle cavity and ejected through the inhalant siphon or along the ventral mantle margin (Berg *et al.* 1996).

In Loay-Loboc River, Bohol, Central Philippines, natural population of *P. erosa* may experience high turbidity condition due to unregulated anthropogenic activities and erratic weather disturbances. Currently, it is not yet known up to what extent *P. erosa* can tolerate the turbidity concentrations that are normally encountered in natural as well as in disturbed mangrove or *Nypa* environments. There are evidences that variations in body size and concentration of suspended particles influence their physiological responses (Rajesh *et al.* 2001, Rueda & Smaal 2002, Hatton *et al.* 2005). Thus, a laboratory experiment was conducted to determine the effect of body size and turbidity concentrations on the filtration rate and pseudofaeces production of *P. erosa* collected in Loay-Loboc River, Bohol, Central Philippines. This study will aid in the development of culture techniques of this species in the region. Results could also be used to facilitate adequate stock management for potential future commercial exploitation in Central Philippines.

At the moment, the *P. erosa* populations in Central Philippines are harvested and considered as low level artisanal fishery for sustenance consumption (Laureta 2008, Argente 2012).

MATERIALS AND METHODS

The clams were collected from a *Nypa* zone in Masayon, Calvario, Loay-Loboc River, Bohol (9.60853° N, 124.01265° E) (Fig. 1). The estuarine river is known for different anthropogenic activities such as fishing, gastropod and bivalve gleaning, recreational boat cruise and sand quarry. Water samples were taken from the collection site to determine the prevailing salinity and total suspended solids (TSS) condition. Substrate samples were also collected for use as suspended particles during the experiment.

The clams were brought to the laboratory (University of San Carlos Marine Station, Mactan Island) within 24 hours after collection and acclimated in a basin filled with filtered brackish water (7 ppt) for 12 hours prior to the experiment. The clams were not fed during the acclimation period. Two size classes of *P. erosa*, smaller-sized clams (47.4±4.3 mm) and larger-sized clams (58.0±2.4 mm) were used during the experiment.

Substrate samples mostly composed of sand and mud were wet sieved to separate the silt (< 63 μm diameter). The silt were air-dried, pounded and oven-dried (75 °C) to constant dry weight. Experimental concentrations of suspended silt were based on the prevailing TSS condition at the collection site. A range finding test was conducted to determine the turbidity concentrations used in the experiment. Consequently, four higher turbidity concentrations (250, 500, 750 and 1,000 mg/L) and a control (40 mg/L) were used.

The experiment employed a Randomized Complete Block Design (RCBD) with the experimental replications as the blocking variable. An experimental unit (Fig. 2) included an individual clam glued on a bamboo stick using aquatic epoxy and placed in a plastic container filled with 1 L filtered brackish water (7 ppt) and silt particles of the established experimental turbidity concentrations. The container was aerated from the bottom to ensure suspension of silt particles throughout the experiment. A piece of plastic was placed above the air source to avoid clam distress which may affect filtration activity. Six replications were conducted for each experimental turbidity concentration per size class.

Each clam was randomly allocated to an experimental unit and a wait-period of approximately five minutes was observed before the actual timing of the incubation experiment which lasted for 120 minutes (2 hours). After the experiment, the clams were removed from the experimental units. Pseudofaeces clinging from the bamboo sticks, clam shells and walls of the containers were collected and placed in pre-labeled petri dishes and oven dried (75 °C) to constant dry weight. The brackish water in the experimental units were filtered using pre-weighed (constant dry weight) Whatmann™ GFC 47 mm filters. The filters with residues were air-dried for 24 hours and oven-dried at 75 °C to constant dry weight.

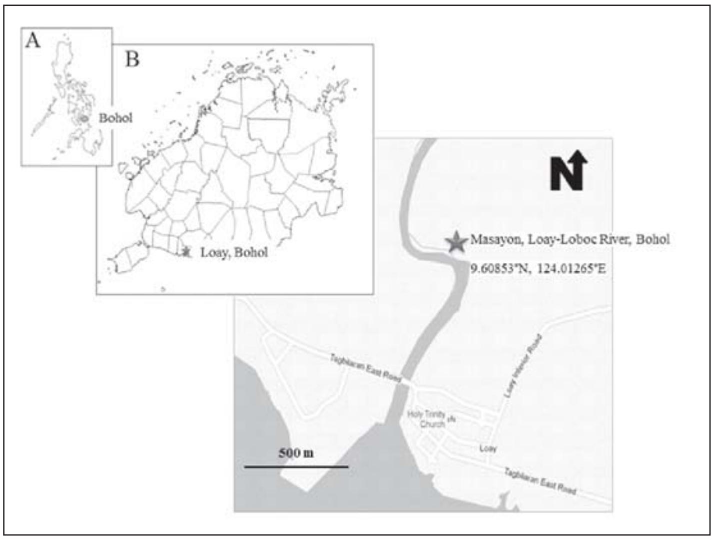

Figure 1. Map of Loay-Loboc River, Bohol, Central Philippines. Collection site is shown with a marker (star). Inset map A is the Philippines, B is Bohol

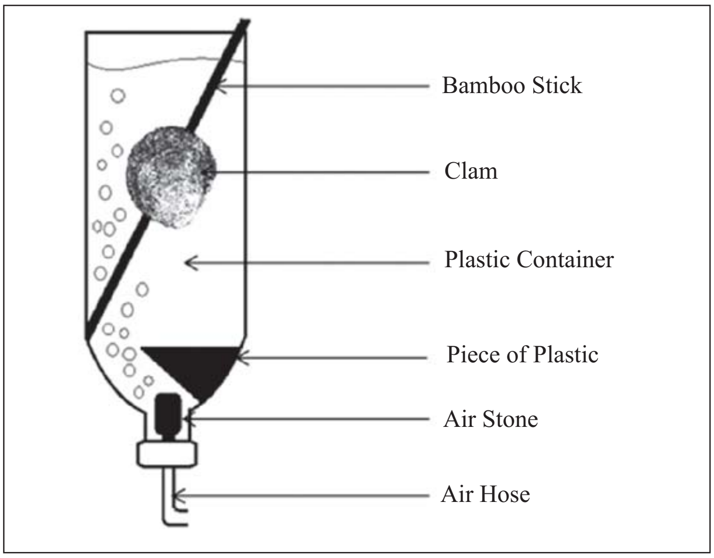

Figure 2. Experimental unit of the study

The filtration rate (FR; mg/minute/ind) and pseudofaeces production (PP; mg/minute/ind) of the *P. erosa* were determined using these equations:

$$FR = [TSS_i - (Filter_r - Filter_i)] / \text{Time elapsed} \quad (1)$$

$$PP = \text{Wt of Pseudofaeces} / \text{Time elapsed} \quad (2)$$

Where:
TSS_i = initial quantity (mg) of total silt in the experimental unit
$Filter_i$ = initial weight (mg) of the filter
$Filter_r$ = weight (mg) of filter with residue
Time elapsed = 120 minutes

A two-way ANOVA (Analysis of Variance) with replications was used to determine the effects of body size and turbidity concentration on the filtration rate and pseudofaeces production of the experimental clam. Raw data were log-transformed (Log+1) to satisfy parametric statistical assumptions. In cases of significant differences, the Tukey HSD test was used as post hoc test. The significance level was set at 95% ($p = 0.05$).

RESULTS AND DISCUSSION

Water Quality Measurement Results

In this study, the prevailing salinity in the sampling area was 7 ppt, while the prevailing Total Suspended Solids (TSS) was 40 mg/L. Total organic matter content of substrate was 30%.

Filtration Rate (FR) and Pseudofaeces Production (PP) of *P. erosa*

Table 1 shows the results of two-way ANOVA on the effects of Turbidity Concentration (TC) and Body Size (BS) to the log-transformed FR and PP of *P. erosa*. TC significantly influenced FR and PP ($p < 0.05$). However, BS showed no significant effect on FR and PP. Likewise, no interaction effect between TC and BS was observed. The log-transformed data showed that the FR of *P. erosa* significantly increased with higher TC up to 750 mg/L, beyond which no significant increase was observe (Fig. 3). Similarly, the log-transformed PP of *P. erosa* also showed significant increased with higher TC (Fig. 4). However, the variations in PP within each TC were wider compared to FR.

Bivalves tend to escalate their filter feeding behavior with higher turbidity conditions (Bayne *et al.* 1993, Rajesh *et al.* 2001). In highly turbid waters, these filter feeders consume much energy to filter suspended particles (Hibbert 1977). Consequently, bivalves have different threshold limits in their filter feeding activities (Berg *et al.* 1996, Rajesh *et al.* 2001). Exceeding beyond the threshold may have negative effects in the physiological responses of these species within their environment. In the work of Morillo-Manalo and Del Norte-Campos (2010) on a burrower bivalve, *Paphia undulata*, the initial increase in filtration rate followed by a decrease at higher

Table 1. ANOVA results on the effects of Turbidity Concentration (TC) and Body Size (BS) to the log-transformed Filtration Rates (FR) and Pseudofaeces Production (PP) of *P. erosa*

Effect	SS	DF	MS	F	*p*-value
Log-transformed FR					
TC	14.114	4	3.528	501.100	0.000*
BS	0.004	1	0.004	0.580	0.448
BS*TC	0.031	4	0.008	1.100	0.369
Error	0.352	50	0.007		
Log-transformed PP					
TC	17.064	4	4.266	130.495	0.000*
BS	0.021	1	0.021	0.640	0.427
BS*TC	0.079	4	0.020	0.604	0.661
Error	1.635	50	0.033		

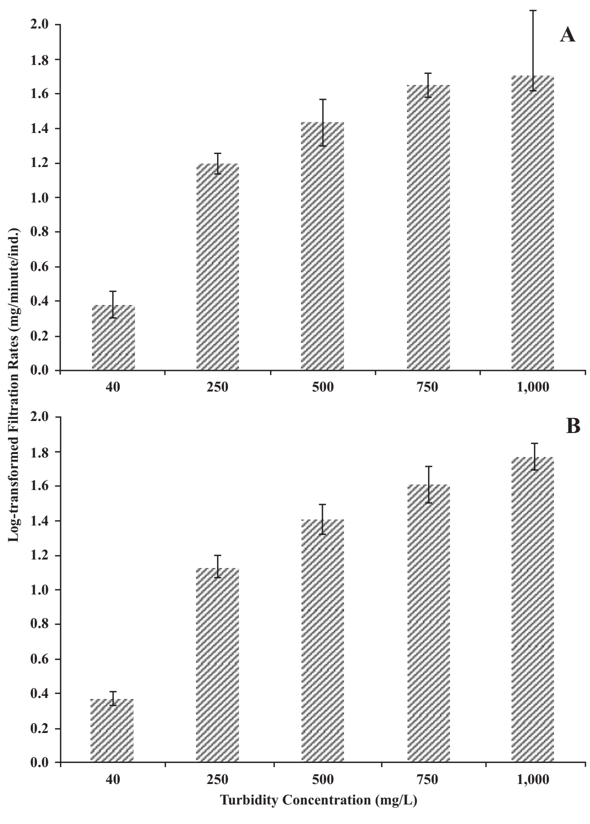

Figure 3. Log-transformed filtration rates of larger-sized (A) and smaller-sized (B) *P. erosa* at different turbidity concentrations *(Bars indicate Standard Deviation)*

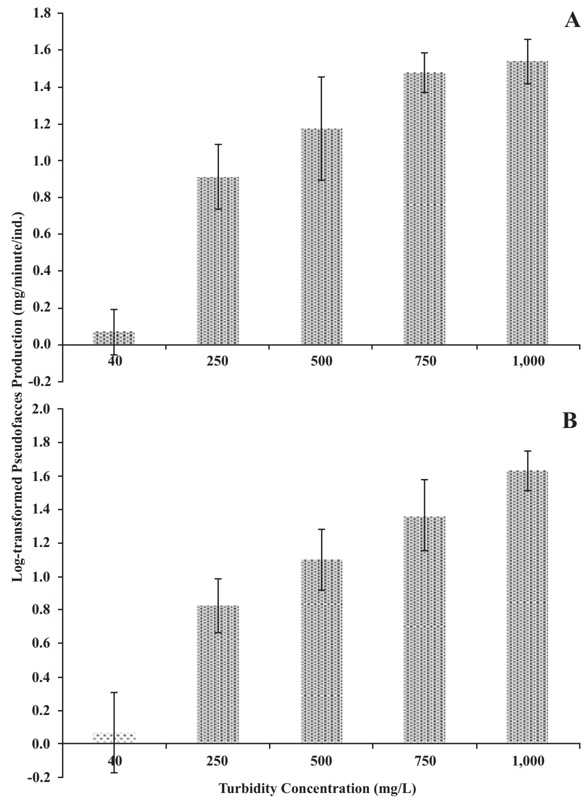

Figure 4. Log-transformed pseudofaeces production of larger-sized (A) and smaller-sized (B) *P. erosa* at different turbidity concentrations *(Bars indicate Standard Deviation)*

concentration, was attributed to the inherent nature of the clam to stimulate valve opening and filtration activity when exposed to lower concentration. Then, at higher concentration, this may result to overloading of the ctenedia, the filter apparatus that led to closing of the valve, thus reduction in FR. However, in this experiment, the plateau of FR was not yet reached. Ecologically, it could mean that *P. erosa* can still withstand higher turbidity level, as in the case during heavy rains of which the Loay-Loboc River receives water from tributaries as far as Carmen (the interior part of Bohol).

The unpredictable weather disturbances and the increasing human perturbations can result in turbid aquatic environments. Bivalves with higher threshold of filtration would be more resilient in disturbed waters. In this study, *P. erosa* showed potential in adapting to such situation. The FR of the clam significantly increased in turbidity conditions of up to 750 mg/L. This was a remarkable feat as compared to *Mytilus edulis*, *Cerastoderma edule* and *Spisula subtruncata* which could filter in turbidity concentrations ranging from 10 to 570 mg/L (Bayne *et al.* 1993, Navarro & Widdows 1997, Rueda & Smaal 2002).

The PP of *P. erosa* showed increasing rate at higher TC. Morillo-Manalo and Del Norte-Campos (2010) stated that the production of pseudofaeces implies maximum energy gain for the bivalves during feeding. *P. erosa* produced more pseudofaeces in higher TC to optimize energy gain instead of utilizing more to metabolize excess particles. This is also a mechanism to regulate ingestion rate as well as preventing saturation of the gills. Iglesias *et al.* (1998) equated FR to ingestion rate, when all filtered material is ingested with no pseudofaeces production. Similar condition was encountered with other bivalves such as *Dreissena polymorpha*, *Spisula subtruncata* and *Paphia undulata* (Bayne *et al.* 1993, Rueda & Smaal 2002, Morillo-Manalo & Del Norte-Campos 2010).

The BS of *P. erosa* did not affect the filtration and pseudofaeces production. During the experiment, the valves of *P. erosa* opened all throughout the incubation period indicating that they were actively filtering regardless of size. In other bivalves such as *Perna canaliculus*, *Perna viridis* and *Crassostrea madrasensis*, these physiological responses tend to increase with larger body size (Rajesh *et al.* 2001, Hatton 2005). Smaller individuals of these species may have little chance of survival in highly turbid waters. On the other hand, the short-necked clam *Paphia undulata* showed a reduction of FR with increasing BS (Morillo-Manalo & Del Norte-Campos 2010). The higher FR by smaller *Paphia undulata* is supposedly needed to support its fast growth and development (Del Norte-Campos & Villarta, 2010), compared to *P. erosa* which is considered to be a long lived species (Morton 1988). Another important consideration here was the range of shell length between the two treatment levels used in the study. A wider range (i.e. juvenile size vs. mature size) in future experiment might reveal important information on the effect of clam size. In this study, we experienced difficulty in obtaining small clams in the collection site.

Ecologically, the filtration of suspended particles and pseudofaeces production are physiological functions of bivalves (Berg *et al.* 1996, Higano 2004). The processing of suspended materials in the water column carried out by suspension filter feeders was significant in assessing trophic relationships in freshwater, estuarine and marine ecosystems (Prins *et al.* 1996, Espinosa *et al.* 2008, Manganaro *et al.* 2009, Sarikhani & Javanshir 2010, Mamun & Khan 2011). This study suggested that natural population of *P. erosa* in Loay-Loboc River was resilient in their environment, which agreed to experiments conducted by Yap and Mohd Azri (2009) and by Bayen *et al.* (2005).

In this time of climate change and rising human population, the search for new and better adapted species for aquaculture is deemed necessary (De Silva & Soto 2009). The resiliency of *P. erosa* to adverse environmental conditions makes it a potential candidate species for aquaculture

CONCLUSIONS

P. erosa population in Loay-Loboc River was resilient with the ability to respond to highly turbid waters. The filtering activity and pseudofaeces production in the population tended to escalate at higher turbidity concentrations up to 750 mg/L. Size is a non-factor in its physiological responses suggesting high survivability in disturbed, turbid waters compared to other bivalves. As a result of its resiliency to adverse environmental conditions, *P. erosa* would be considered as potential candidate species for aquaculture in Central Philippines.

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